

Congestive Heart Failure in Infants and Children

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CONGESTIVE HEART FAILURE occurs in as many as 10 to 20 per cent of all cases of heart disease in infants and children. The response to proper treatment of this condition is often dramatic and life saving.

Causes of Heart Failure

Most cases of heart failure in infants and children are due to congenital heart disease of one kind or another. In early infancy aortic atresia and transposition of the great vessels may give rise to failure, and treatment may be of only temporary benefit.⁴ However, such curable lesions as patent ductus arteriosus, coarctation of the aorta and severe pulmonary stenosis may also be complicated by congestive failure which, if properly recognized and treated, may subsequently permit the surgical correction of the lesion. Combined lesions such as patent ductus arteriosus associated with an interventricular septal defect or with aortic stenosis are particularly likely to bring about heart failure in infancy.

In addition to congenital heart disease there are other conditions which may cause heart failure, among them pronounced anemia, hypothyroidism, sickle cell crisis, acute glomerulonephritis, paroxysmal atrial tachycardia,² thyrotoxicosis, diphtheria, "beri-beri heart," administration of desoxycorticosterone acetate or other steroids, rheumatic fever, cerebral vascular accident, subacute bacterial endocarditis, constrictive pericarditis, coronary artery occlusion, fibroelastosis and nonspecific myocarditis.

Clinical Features of Congestive Cardiac Failure

The clinical features of congestive failure are sometimes difficult to recognize in an infant or child and are often confused with those of infection. It is difficult if not impossible to differentiate between left heart and right heart failure in the young age group.⁷ In general, signs of right heart failure predominate, and are:

1. *Rapid respirations.* The normal respiratory rate at birth and soon thereafter is approximately 40 per minute. It may range from 50 to 100 per minute and still not be identified as a sign of abnormality. Of course fever, particularly associated with a pulmonary infection, may produce rapid

• Congestive failure in infants and children is not uncommon and may be present in a varying number of conditions, particularly in certain types of congenital heart disease. Its recognition and proper treatment are usually followed by improvement, except in those instances where the failure is associated with a lesion incompatible with life. The essentials of treatment are: Treatment of the underlying cause, administration of a digitalis preparation, low salt diet, diuretics, rest and sedation, oxygen, adequate diet and, in rare instances, the use of steroids.

respirations. In cyanotic heart disease rapid respirations may be due to associated attacks of cerebral anoxia and not congestive failure; and the treatment for these two conditions is entirely different.

2. *Hepatomegaly.* The lower edge of the liver is easily palpated in infancy and can be one to two centimeters below the right costal margin without abnormality. The edge may be even lower in the presence of respiratory infection causing increased expansion of the lungs—as in bronchiolitis—in which case it is not enlarged but merely displaced caudally. Usually in such circumstances the spleen is more easily palpable. In true congestive failure, however, the liver is usually decidedly enlarged and the lower edge may be percussed or palpated at the umbilicus. Hepatomegaly not only is a sign of congestive failure, but a decrease in size is an excellent criterion of response to therapy.

3. *Cardiac enlargement.* Cardiac enlargement usually precedes and accompanies congestive heart failure.⁹ In infants and children the size of the heart is difficult to determine radiologically, particularly if there is a superimposed thymic shadow. A greatly enlarged cardiac shadow unassociated with signs of congestive failure should lead to the suspicion that the shadow is not due to an enlarged heart.

4. *Tachycardia.* Although the rate is difficult to evaluate in a crying or moving child, a rate of 120 per minute or over in the absence of fever or crying, and when accompanied by rapid respirations and hepatomegaly, is indicative of tachycardia.

5. *Gallop rhythm.* A gallop rhythm usually denotes congestive failure, but this rhythm must be differentiated from the physiological third heart sound.

6. *Pulmonary rales.* Rales may be heard at both lung bases but are infrequent in infants, and when

Presented before the Section on Pediatrics at the 86th Annual Session of the California Medical Association, Los Angeles, April 28 to May 1, 1957.

TABLE 1.—Data on Administration, Action, Duration and Toxicity of Various Digitalis Preparations

Agent	Method of Administration	Onset of Action	Time for Maximum Effect	Duration of Effect	Maximum Duration Toxicity
Digitalis leaf.....	Oral.....	6 hr.	12 to 48 hr.	17 days	1 to 2 weeks
Digitalis, injection USP.....	Intravenous or intramuscular.....	2 hr.	6 hr.	17 to 21 days	1 to 2 weeks
Gitalin.....	Oral.....	24 to 48 hr.	10 to 12 days
Digitoxin.....	Intravenous or intramuscular..... Oral.....	30 min. 2 hr.	2 to 9 hr.	21 days	3 weeks
Digoxin (lanoxin)	Intravenous or intramuscular..... Oral.....	30 min. 2 hr.	4 to 6 hr.	4 to 7 days	1 to 2 days
Lanatosid C or D (Cedilanid)	Intravenous or intramuscular..... Oral.....	10 to 30 min. Absorption indefinite	2 to 3 hr.	2 to 3 days	1 day
Oubain.....	Intravenous.....	5 min.	30 min.	1 to 4 days	2 to 6 hr.
Acetyl strophanthidin.....	Intravenous.....	½ to 5 min.	12 min.	2 hours	30 min.

present are difficult to differentiate from those due to the pulmonary infection which frequently accompanies failure.

7. *Peripheral edema.* Edema is a very late sign of failure in infants and children. It indicates a very severe degree of failure.

8. *Easy fatigability.* This sign may be an important clue in detecting congestive failure in infants, and often it is the mother who notices that the infant pauses frequently to rest during his feedings.

The determination of venous pressure, vital capacity and circulation time is difficult in infants and small children, and are then only confirmatory procedures utilized after congestive failure has already been suspected by other signs and symptoms.

Treatment

Proper treatment of heart failure depends upon the application of certain fundamental measures, without, however, undue reliance on any one phase of treatment, and with close observation at all times. These fundamentals include:

1. *Treatment of the underlying condition.* Congestive failure is often precipitated by an infection or electrolyte imbalance, particularly in a child with a low reserve. Hence a child with pneumonia and heart failure should be vigorously treated with antibiotics, and one who has pronounced anemia should have careful replacement of blood. In conditions such as coarctation of the aorta, patent ductus arteriosus and severe pulmonary stenosis, surgical intervention must not be postponed too long, for operation may be the only way congestive failure may ultimately be relieved.

2. *Digitalis.* Use of a digitalis preparation is the basis of treatment for congestive failure.⁶ There is nowadays no general reluctance to use such preparations in infants and children. One must not rely

on it too much; although in most instances an average digitalizing dose will be effective,¹ the individual variability of response must be kept in mind. Whichever digitalis preparation is used, the therapist must be familiar with certain basic factors concerning it: The average digitalizing dose for the age and weight of the infant or child, the rapidity of action by both oral and parenteral routes, and the signs of toxicity. The most commonly used preparations are: Digitalis leaf or tincture, digitoxin, Digoxin® (lanoxin),⁸ lanatosid C or D, acetyl digitoxin (Acyland®) and Gitalin.⁹

Digitalis leaf acts slowly and dissipates slowly. Lanatosid C or D acts rapidly and is swiftly dissipated. The other preparations are between these extremes. Table 1 shows the method of administration, the onset of action, the time for maximal effect, duration of effect and the maximal duration of toxicity for each of the preparations mentioned. The usual method of administration and the digitalizing doses of these preparations are shown in Table 2. It is extremely important that one learn the vagaries of one or more preparations well, particularly with glycosides (the dose of which is 1/1000 that of a whole leaf preparation) for errors of dosage or in calculation of duration of effect may be disastrous.

It is difficult to determine how long to continue administration of digitalis once the congestive failure has been controlled. In general it may well be continued beyond the time the underlying cause has been eliminated. In prolonged administration of digitalis to an infant, the relatively rapid weight gain in this age group must be kept in mind, lest the patient outgrow the calculated dose.

One must not rely on digitalis alone, increasing doses to the point of toxicity before resorting to adjunctive therapeutic measures such as low salt diet and mercurial diuretics, or before investigating the reasons for ineffectiveness of the preparation. For

TABLE 2.—Dosage of Various Digitalis Preparations for Infants* and Children*

Agent	Method of Administration		Digitalizing Dose	Maintenance Dose
Digitalis leaf.....	Oral.....	Infant.....	15 mg./lb.	1/10 total digitalizing dose
		Child.....	10 mg./lb.	
		Adolescent or adult.....	1.2 to 2.0 gm. (average 1.5 gm.)	
Gitalin.....	Oral.....	Infant.....	0.02 to 0.04 mg./lb.	1/10 total digitalizing dose
		Child.....	0.01 to 0.02 mg./lb.	
		Adolescent or adult.....	3.0 to 10.5 mg. (average 5.7 mg.)	
Digitoxin.....	Oral, intravenous or intramuscular.....	Infant.....	0.02 to 0.03 mg./lb.	1/10 total digitalizing dose
		Child.....	0.01 to 0.02 mg./lb.	
		Adolescent or adult.....	1.3 to 2.0 mg. (average 1.7 mg.)	
Digoxin (lanoxin).....	Intravenous or intramuscular.....	Infant.....	0.02 to 0.03 mg./lb.	1/10 to ¼ total digitalizing dose
		Child.....	0.01 to 0.02 mg./lb.	
		Adolescent or adult.....	0.75 to 1.0 mg. (average 0.8 mg.)	
	Oral.....	Infant.....	0.03 to 0.04 mg./lb.	
		Child.....	0.02 to 0.03 mg./lb.	
		Adolescent or adult.....	2.0 to 5.0 mg. (average 3.75 mg.)	
Lanatosid C or D.....	Intramuscular or intravenous.....	Infant.....	0.01 to 0.02 mg./lb.	1/10 to ¼ total digitalizing dose
		Child.....	0.008 to 0.01 mg./lb.	
		Adolescent or adult.....	1.2 to 3.2 mg. (average 1.6 mg.)	
Oubain.....	Intravenous.....	Infant.....	0.006 to 0.008 mg./lb.	Not used
		Child.....	0.006 to 0.008 mg./lb.	
		Adolescent or adult.....	0.6 to 1.0 mg. (average 0.7 mg.)	

Safe average digitalizing dose for purified glycosides 0.015 mg./lb.

* Infant is under 2 years; child is 2 to 12 years.

example giving digitalis to a patient with hypokalemia may result in toxic arrhythmias without having any therapeutic effect until the potassium level is brought up to normal.^{1,5} Sometimes when manifestations of digitalis toxicity develop, administration of potassium may relieve them even though the blood potassium content is already normal. It must also be kept in mind that since calcium and digitalis are synergistic, one must be cautious in using them simultaneously or consecutively.³

3. *Low salt diet.* A low salt diet is an invaluable adjunct in the treatment of congestive failure. In infants the administration of Lonolac,[®] a powdered milk, or the use of one of the recent low-salt evaporated or whole milk preparations which are now available in California should be instituted at the same time as the administration of the digitalis in any case of severe congestive failure. After the acute phase is over, it may be possible to permit the infant to have a modified or even regular salt intake without ill effect.

4. *Diuretics.* If digitalis and a low salt diet are not completely effective, use of a diuretic is indicated. There are several available preparations of both the mercurial and nonmercurial types. Thiomerin[®] (mercaptomerin sodium) has been used in

pediatric cardiology because it can be given subcutaneously, and it is now very widely used in adult cardiology, as it seems to be somewhat safer than other preparations. The administration of 0.1 cc. of Thiomerin subcutaneously as a test dose can be followed by the administration of 0.12 to 0.25 cc. to an infant under one year, and 0.25 to 0.5 cc. to older children. It is usually best to give it every other day, and to discontinue it as soon as a response is obtained and maintained. Other diuretics such as Mercuhydrin[®] (meralluride sodium) may also be used. An oral preparation known as Diamox[®] (acetazoleamide), a carbonic anhydrase inhibitor, may be given in a dose of 2 to 3 mg. per pound of body weight per day. With the administration of mercurial diuretics, two precautions must be observed: (1) The loss of chlorides may produce alkalosis, which will make the mercurial diuretic ineffective until the loss is restored; (2) with pronounced diuresis a low salt syndrome may develop, with drowsiness and even stupor,³ particularly in very warm climates. The rapid loss of fluid in diuresis may result in hypopotassemia, which may not only render the further administration of digitalis ineffective but result in digitalis intoxication.

5. *Rest and sedation.* Bed rest, and in some in-

stances the orthopneic position, are necessary. If drugs are necessary for complete rest, they should be given phenobarbital if it is adequate, and, if not, morphine sulfate in a dosage of 1 mg. per 10 pounds of body weight. Tranquilizers may merit consideration but they have not yet been used enough for this purpose to be recommended.

6. *Oxygen*. Oxygen administered in approximately 40 to 50 per cent concentrations seems to have a sedative effect in many cases, and also slows both the pulse and respirations. If pulmonary edema is present, oxygen should be bubbled through 50 per cent ethyl alcohol and given for five to ten minutes every hour or half-hour.

7. *Diet*. The diet should be essentially fluid in the early stages of treatment, after which a nutritious diet high in vitamin content should be used, with regulation of sodium content as needed.

8. *Cortisone*. Although steroids themselves may be a cause of congestive failure in rare instances, it has been reported that the use of cortisone or corticotropin (ACTH) may relieve severe cardiac failure due to rheumatic fever in some cases. They must be used with caution, however.

9. *Phlebotomy or venesection*. This measure is rarely used, but has been helpful in instances where overzealous administration of blood postoperatively has resulted in the precipitation or aggravation of heart failure.

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REFERENCES

1. Friedman, M., and Bine, R., Jr.: Observations concerning the influence of potassium upon action of digitalis glycoside (lanatosid C), *Am. J. M. Sc.*, 214:633, 1947.
2. Hubbard, J. P.: Paroxysmal tachycardia and its treatment in young infants, *Am. J. Dis. Child.*, 61:687, 1941.
3. Kay, C. F.: The clinical use of digitalis preparations, *Circulation*, 12: No. I and II, Part I, July, 1955, Part II, Aug. 1955.
4. Keith, J. D.: Congestive heart failure, *Pediatrics*, 18:491, 1956.
5. Lown, B., and Levine, S. A.: *Current Concepts in Digitalis Therapy*, Little, Boston, 1954.
6. Movitt, E. R.: *Digitalis and Other Cardiotonic Drugs*, Oxford University Press, New York, 1949.
7. Robinson, S. J.: Treatment of congestive failure in children, *Am. Pract. and Dig. of Treat.*, 2:696, 1951.
8. Sapin, S. O., Donoso, E., and Blumenthal, S.: Digoxin dosage in infants, *Pediatrics*, 18:730, 1956.
9. Taussig, H. B.: *Congenital Malformations of the Heart*, Commonwealth Fund, New York, 1947.

